A Modular and Dispatchable Battery Storage System

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Electrochemical Materials and Systems

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Project Scope and Stakeholders

- Scope:
  - Year 1: Development of test protocol and control strategy. Preliminary testing at BPA, followed by integration with Energy Northwest's Nine Canyon wind farm of a 120 kW, 500 kWh Li-Ion ESS
  - Year 2: Testing of ESS (demand response) at City of Richland Sub-station feeder line and integration with PNNL PV system.
- Project Stakeholders:
  - Powin Energy
  - Bonneville Power Administration
  - Energy Northwest
  - City of Richland, Washington
  - Pacific Northwest National Laboratory

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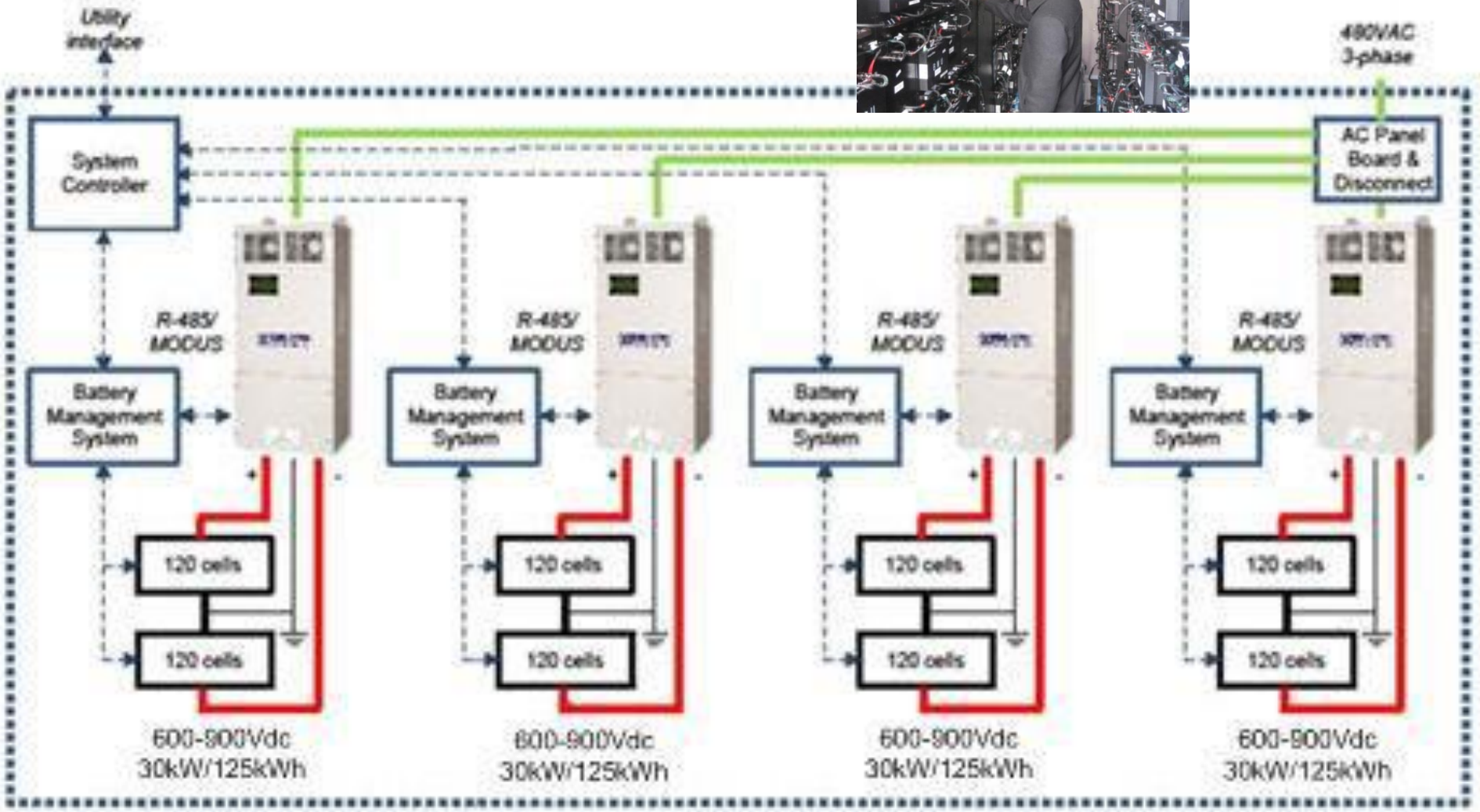
Project Synopsis

- Remote control and testing of a 120kW/500kWh battery storage unit for multiple grid services over a two-year period
- Phase I – applied the ESS performance protocol (DOE-OE sponsored effort led by PNNL-Sandia in collaboration with stakeholders)
- Phase 2 – Various use cases tested at the 96 MW Energy Northwest Nine Canyon wind farm
- Phase 3 – Peak shaving at the City of Richland substation using PNNL-developed load forecast model
- Phase 4 – PV smoothing and firming at the 120 kW PV farm at PNNL

"Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems," (PNNL-22010)

Powin Energy Battery



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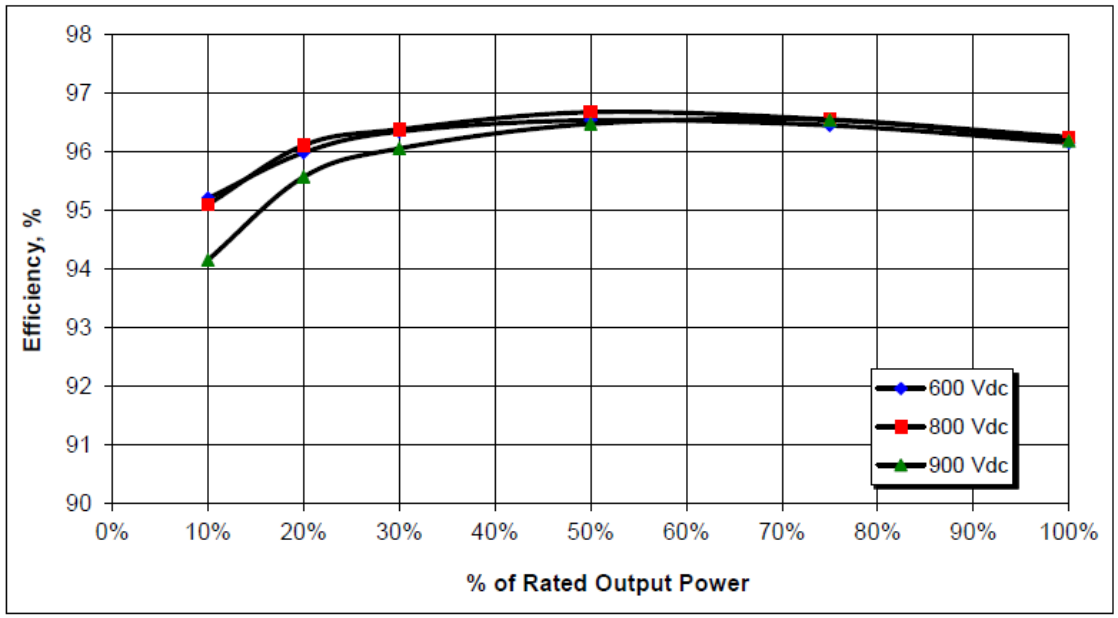
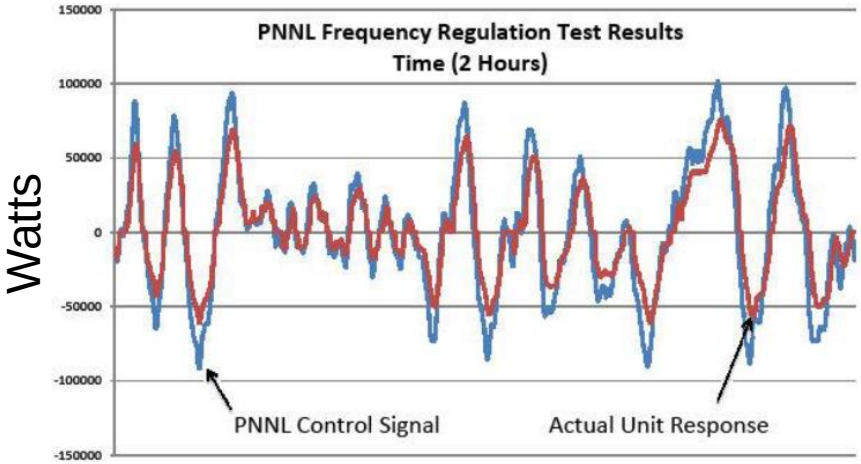
Phase I - BPA Ross Complex

- Testing done at BPA Ross Complex Medium Power Lab
- Lab has a dedicated 13.8-kV, three-phase, 60 Hz, feeder.
- BPA Labs refurbished a 13.8 kV to 480 V transformer
- Revenue grade meter attached to the 480V side of the transformer
  - Max AC charge power: 147 kW
  - Max AC discharge power: 136 kW
- PCS charge-discharge efficiency measured at various power levels (91-95% each way)



Phase I. Testing at BPA Ross Complex

- House loads and standby power draw determined
  - House load transformer
  - Ventilation fans, HVAC added after testing at Ross labs
  - Standby power for PCS determined
- DOE-OE protocol released in 2012
  - Peak shaving and frequency regulation duty cycles tested
  - Round trip efficiency, 84 to 86%.
  - Best efficiency obtained when PCS run at higher end of power range and low house loads
  - Ramp rates during charge and discharge
    - 2.4 kW/s during charge, and 3.78 kW/s discharge



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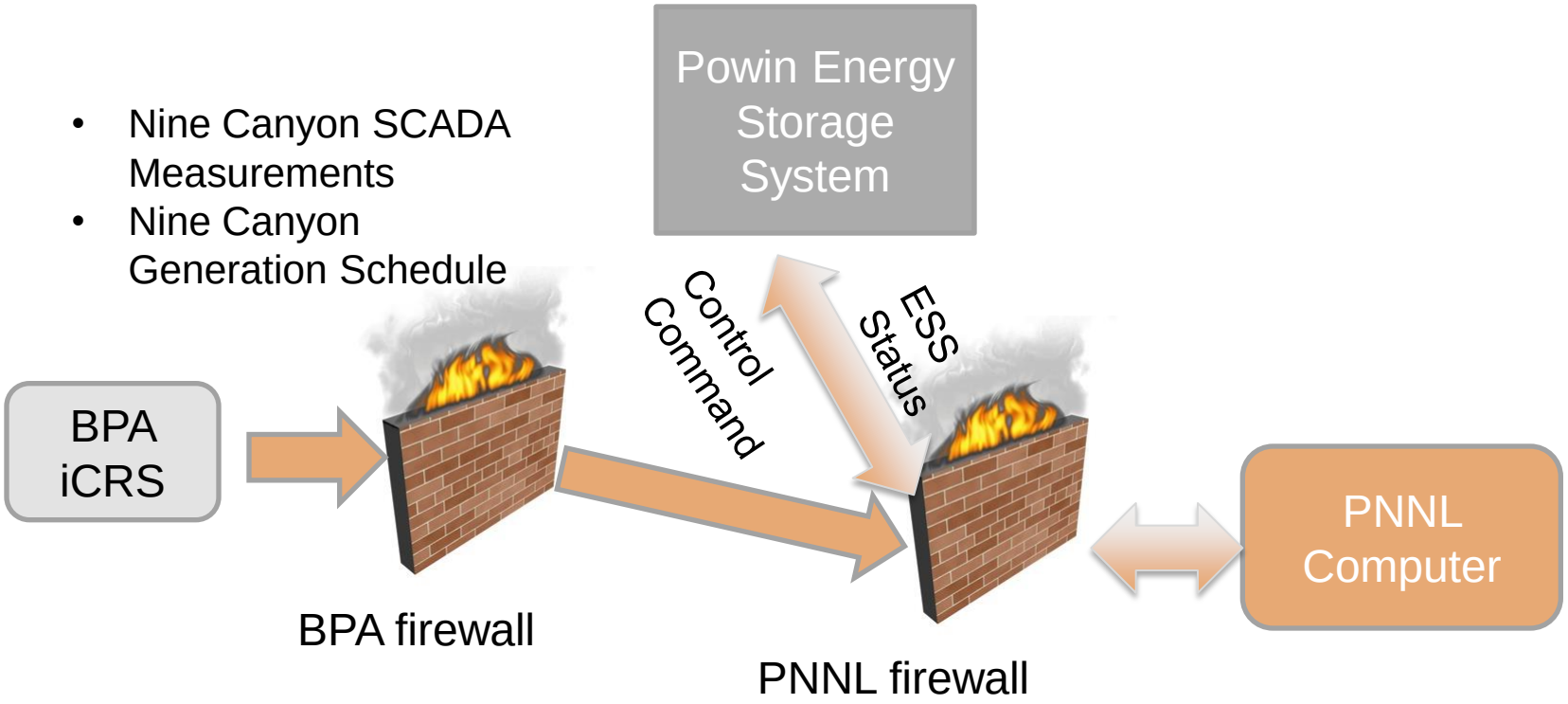
Phase II. Communication and Control

- Nine Canyon SCADA Measurements
- Nine Canyon Generation Schedule



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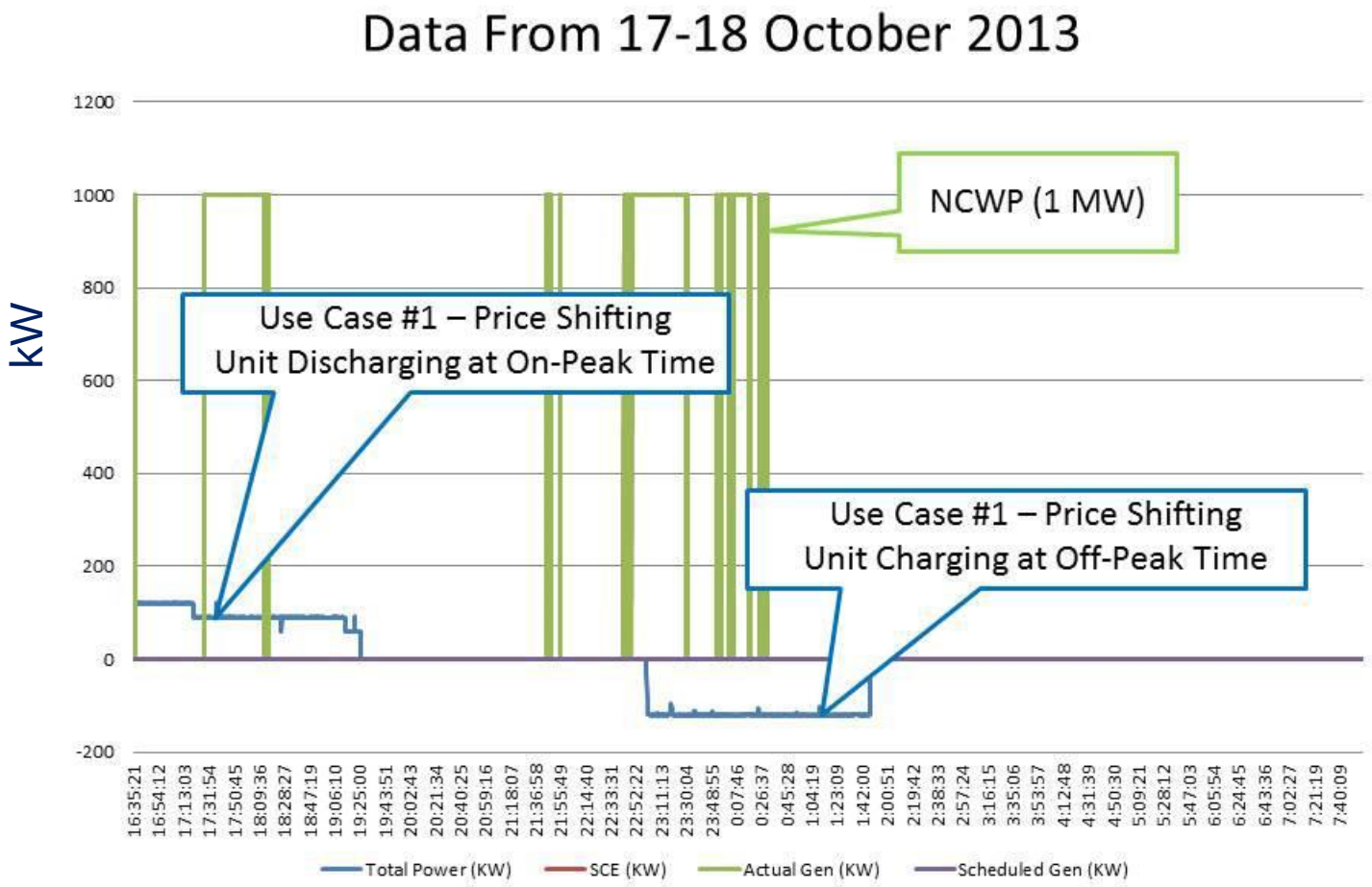
Phase II. Wind Integration

- **96 MW wind farm at Energy Northwest's Nine Canyon Wind Farm.**
- **Address operational challenges facing BPA for wind integration**
- **Use Case 1: Load Shifting**
  - **Objective:** shift energy production of a non-dispatchable, intermittent grid-scale generation resource (Nine Canyon Wind) from lower to a higher value market hour.
- **Use Case 2: Manage to Schedule**
  - **Objective:** remotely control multiple Powin ESS which can be placed in one location or multiple locations to manage the deviation between Nine Canyon hourly schedule and actual generation to reduce penalty charge.
- **Use Case 3: Curtailment Event Compliance Support**
  - **Objective:** remotely control multiple Powin ESS to help Nine Canyon ramp down to the required schedule within 10 minutes (from the issuance of BPA curtailment command).

Phase II. Load Shifting



- Store off peak energy
- Discharge during peak hours
- Successfully demonstrated

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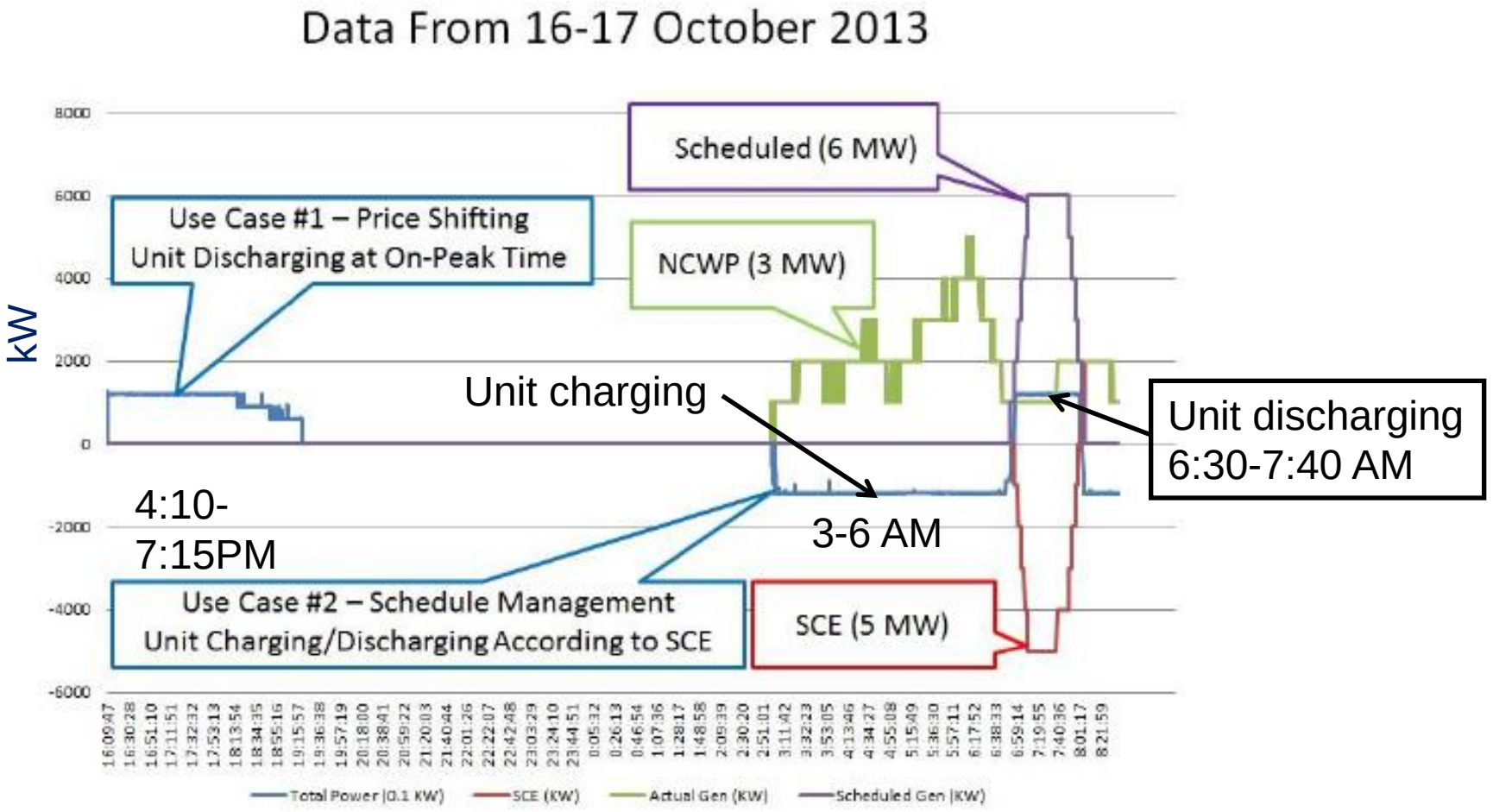
Phase II. Manage to Schedule



- Inputs: Nine Canyon generation (using iCRS)
- Scheduled generation (using iCRS)
- Outputs: charge and discharge commands send to the BESS
- Emails sent to a scheduler

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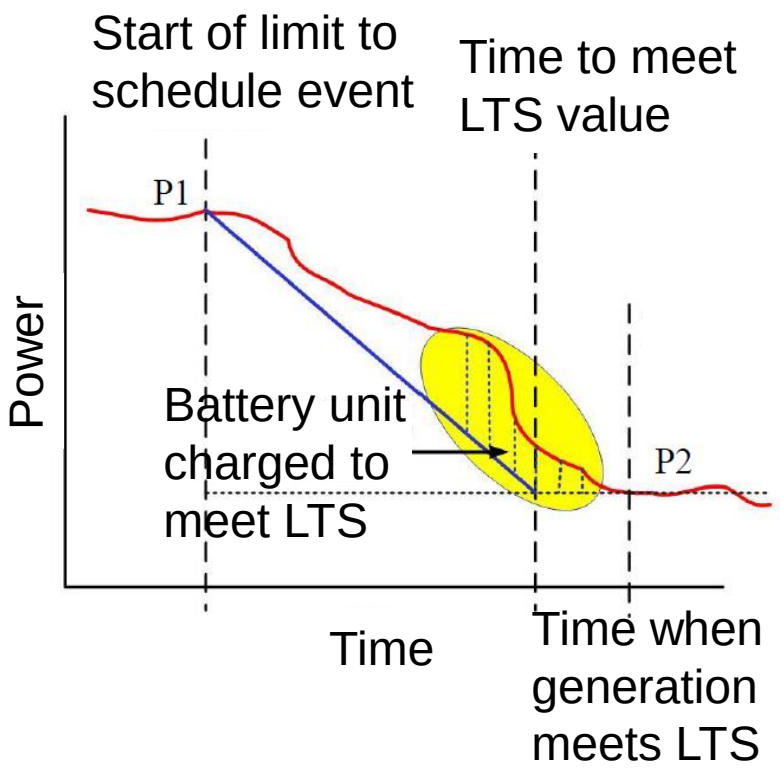
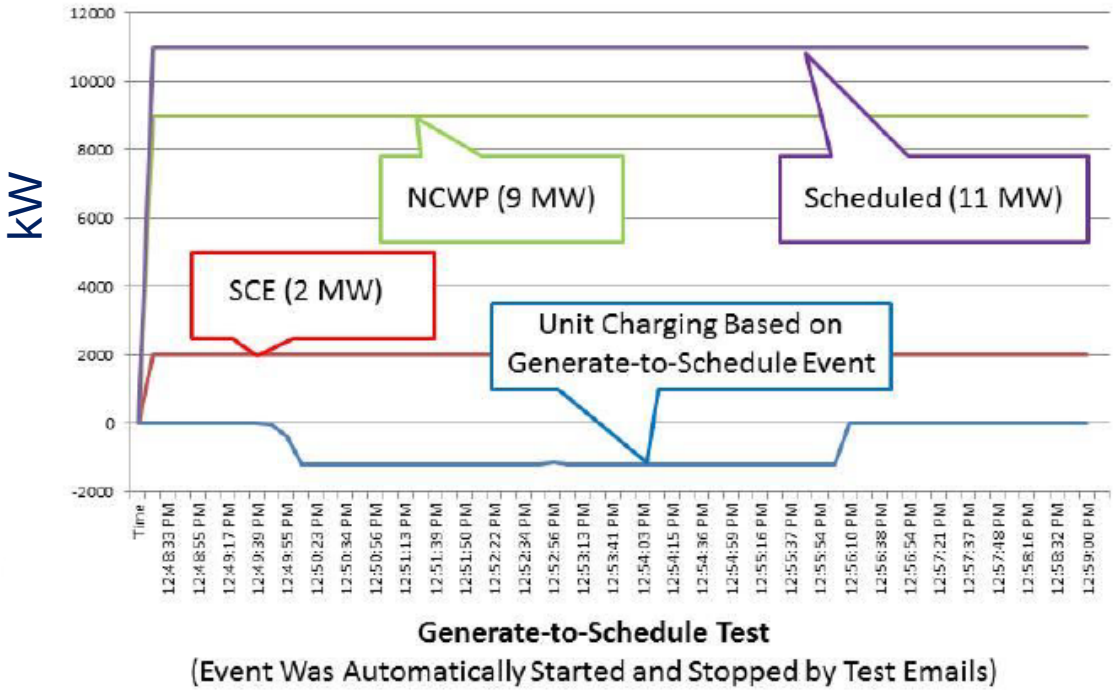
Phase II. Ramp Rate Management





12:50 to 12:56 PM

- **<u>Inputs</u>: Nine Canyon generation (using iCRS)**
- **desired limit to schedule (LTS) power level**
- **Limit to schedule emails sent by automatic dispatch program**
- **End of limit to schedule event**
- **Scheduled generation (using iCRS)**
- **<u>Outputs</u>: charge and discharge commands send to the BESS**
- **Emails sent to a scheduler**

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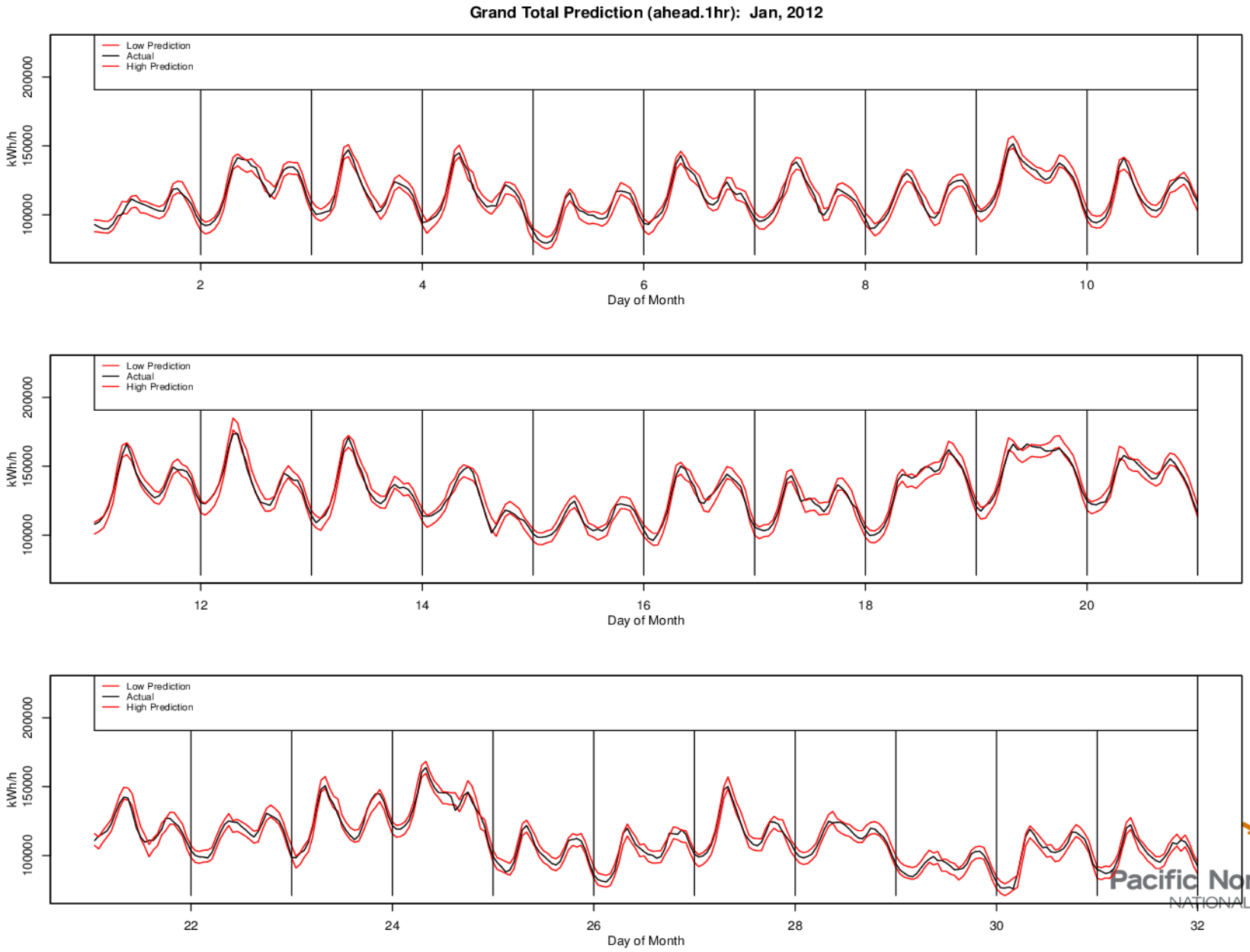
Phase III, City of Richland

- Help reduce load at a City of Richland Substation by discharging at peak hours
- Unit continued to do the 3 use cases from Stage Gate 3
- PNNL developed model(s) to forecast load
  - Three hours ahead (today's focus)
  - Day ahead
  - Month ahead
- Eventual goal is to optimize (minimize) cost to city
  - Deploy peak shaving at the right times
  - On the right days
  - To lower peak charges at minimum cost & wear on load shifting assets
- City of Richland provides access to multiple years' hourly load data and information on monthly thresholds and MW costs above those thresholds

Load Forecasting

- Regression tree method
- Neutral Network method
- Input:
  - Historical load
  - Historical dry bulb temperature
  - Historical dew point temperature
  - Forecast temperature
  - Type of day – working or holiday

Hour ahead forecast for January 2012



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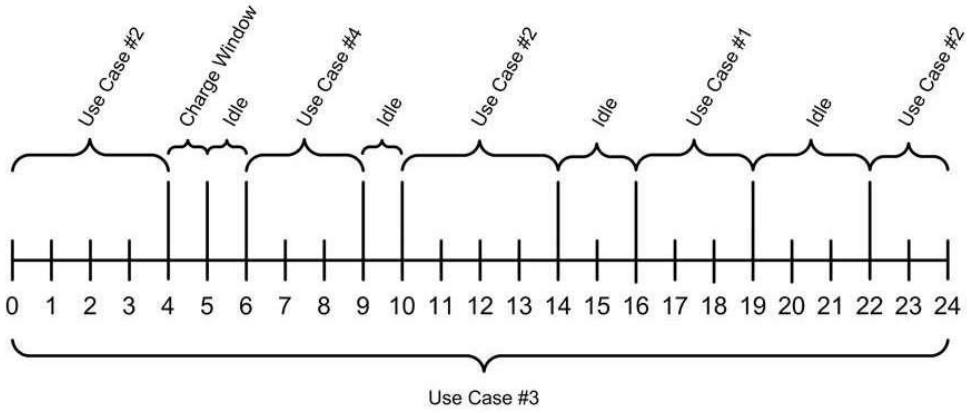
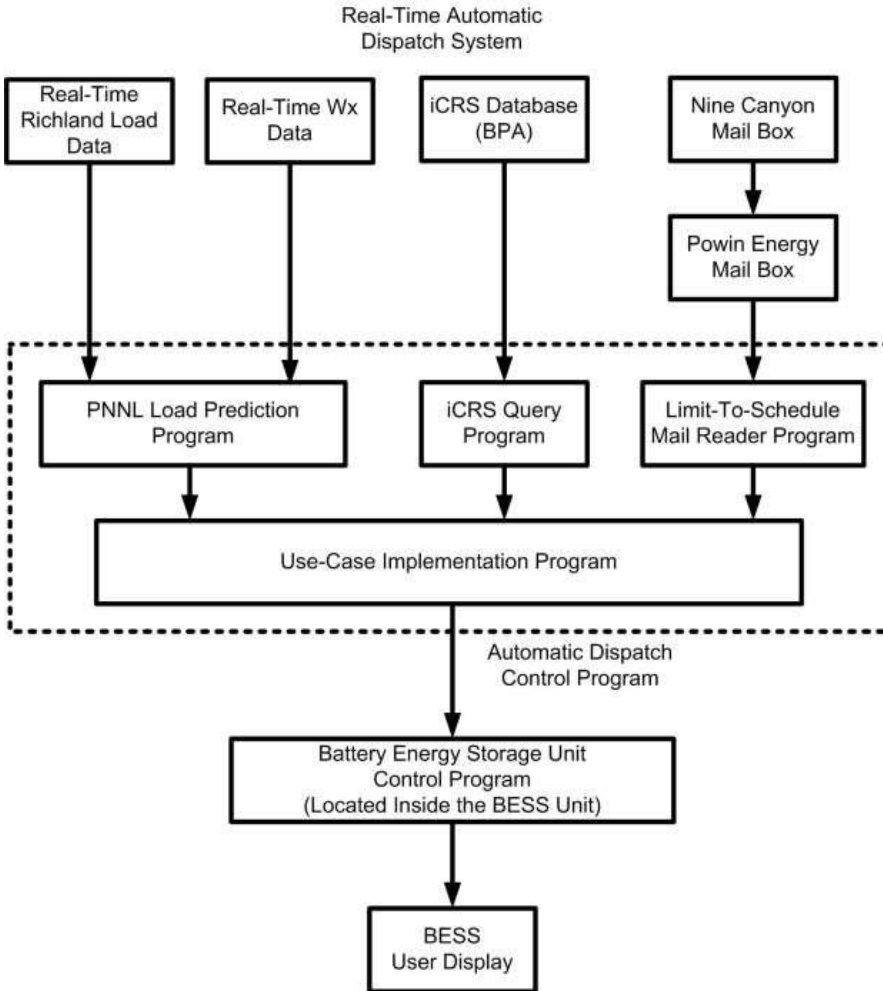
Phase III City of Richland

- Parked next to a 480 V transformer located roadside
- Unit connect by City of Richland to a breaker in the substation
- Electrical connection from transformer to electrical disconnect on the unit inspected by State of Washington Department of Labor and Industries Electrical Inspector





Unit was set up to discharge for 1h in the 6-9AM range based on PNNL load forecast

Unit continued to do use cases 1, 2 and 3 during rest of the day

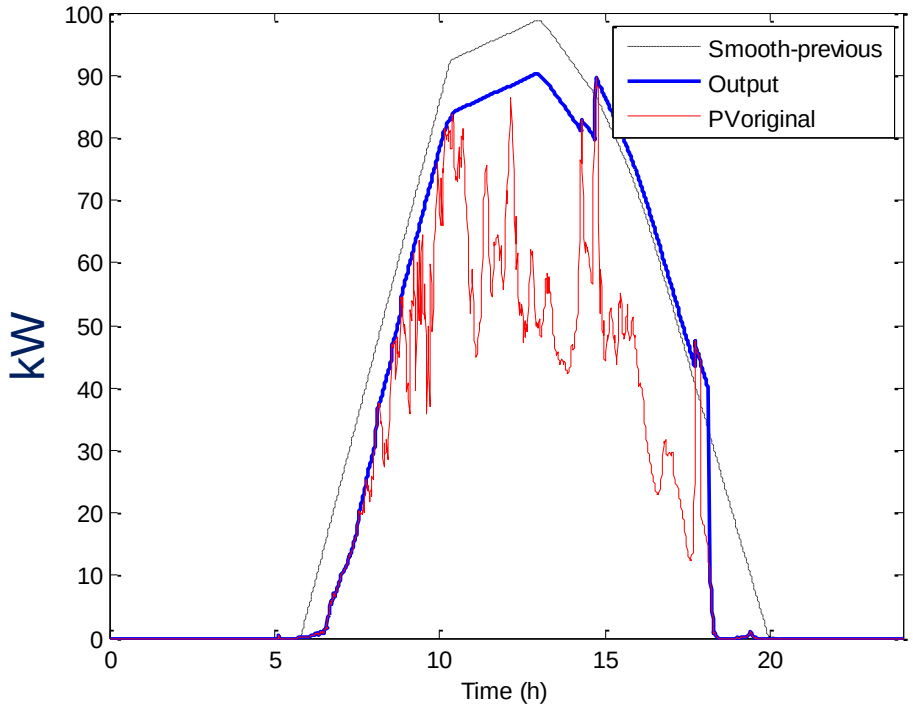
Phase IV – PV Smoothing

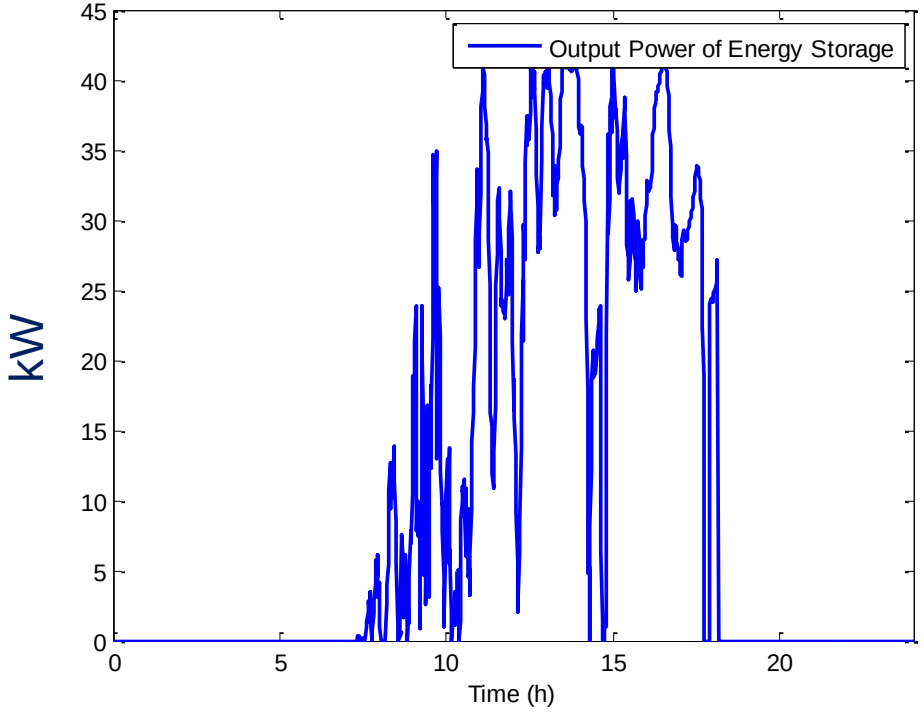
- Unit integrated with 120 kW PV farm located in PNNL campus
- Safety reviews conducted prior to moving storage unit to campus
- Storage connected to control panel that is fed by PV farm and grid
- Control panel feeds 6 MW peak load in the EMSL building
- PNNL facilities provided the cable that hooks up with unit disconnect

Phase IV – PV Smoothing

- Smoothing done for two cases:
  - Case I Assume no peaker plant available for load following
  - Case II Peaker plant available for load following
- PNNL developed algorithm for case I
- DOE-OE PV smoothing group approach used for Case II
- Case I - Use previous day's PV output to calculate projected PV output without cloud cover once ESS is triggered. ESS discharges till PV output equals projected output
- Case II - 20 min moving average used to smooth curve. Set a criterion for peaker plant ramp rate to be less than one third rated power/min.
- Firming – previous day's PV output used to set the desired output for each hour. Charge or discharge ESS to provide needed power.

Phase IV – Case I Simulation results





Storage SOC decreases by 50% of its total SOC during this smoothing

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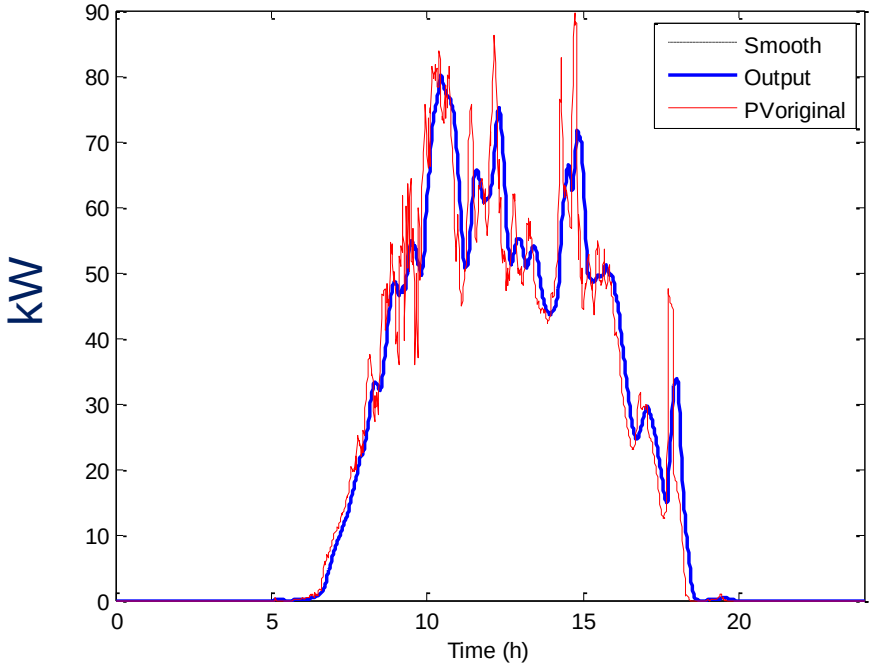
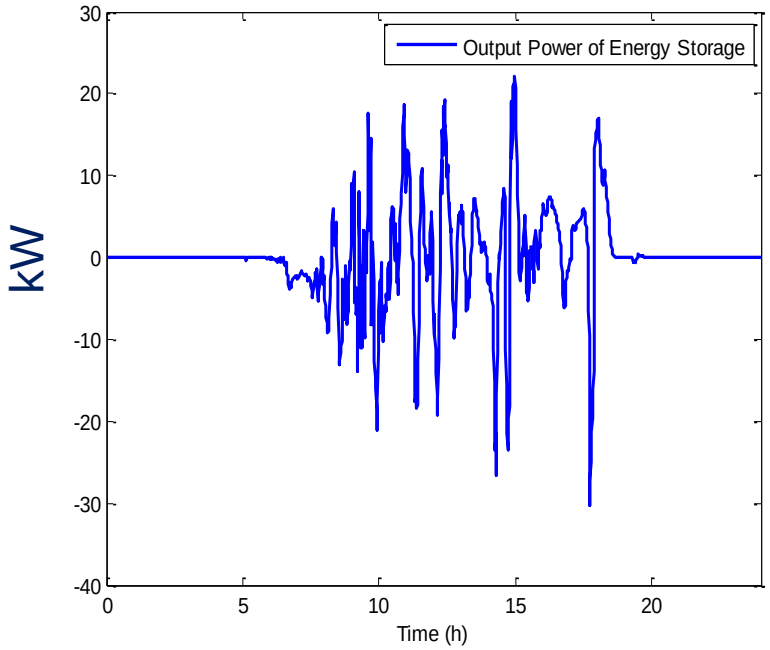
Phase IV – Case II Simulation results





Storage SOC almost unchanged during this smoothing

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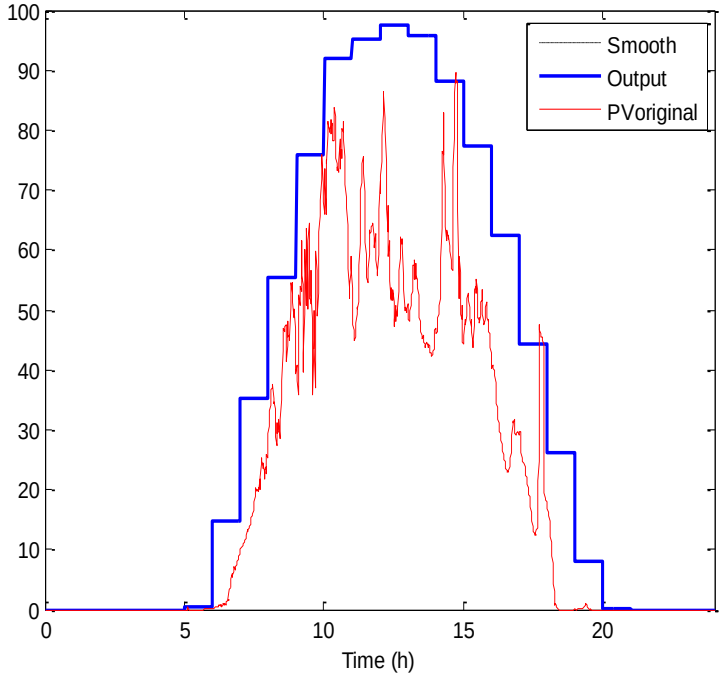
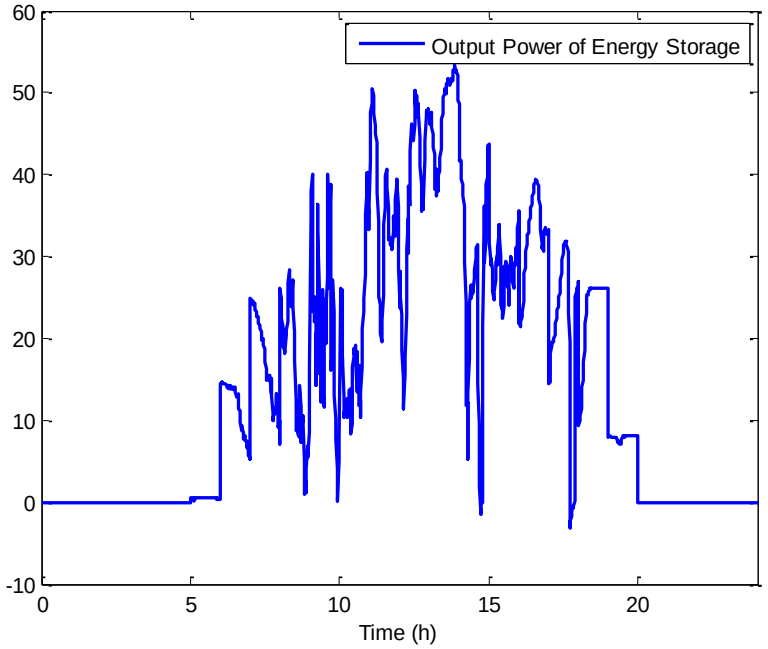
Phase IV – Firming results





Storage SOC decreases by 0.7 times total capacity during firming

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Conclusions

- 120 kW/500 kWh Li-Ion Battery Storage System successfully deployed at 3 sites
- DOE-OE protocol validated
- Communications related issues resolved
- Algorithms for ESS control developed and validated
- Wind integration use cases demonstrated (use case I-III)
- City of Richland Substation peak load shaving done (use case IV)
  - PNNL developed load forecasting tool to forecast peak hour over next 3 hours, next day, next week.
- Dispatch algorithm that prioritizes all the use cases
- Algorithms developed for PV smoothing and firming
- Lessons learnt will enable smart deployment of energy storage acriss a suite of applications

Acknowledgements

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